Solving the Decibel Dilemma

DB or not dB, that is the question. Did you ever wonder what that mysterious "dB," mentioned in so many places, really means? In this issue, W6TNS explains the mysteries of the decibel, particularly as they relate to ham radio.

It ain't easy being a decibel...they're so misunderstood by so many people. Even the newest ham has heard the term dB mentioned when discussing handheld radios or when reviewing specification sheets for amateur products. But few newcomers (not to mention a lot of old timers) really understand the ins and outs (or rather, the ups and downs) of dBs.

The term decibel always represents the same thing, but it does not refer to a specific unit, like feet or pounds. In other words, a dB isn't a specific item; rather, it's a ratio between two values. It can refer to sound energy, power, or voltage, but it always expresses a ratio or change between the two values.

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Think Earthquakes

It might be easier to digest the dB by relating it to something a bit more familiar—such as earthquakes. I'm sure you've heard of the Richter scale, particularly if you live in California. It was devised in 1935 by Dr. Charles Richter of CalTech, to measure the force of quakes. The earth movement S-waves were measured by a Wood-Anderson seismograph. The device was so sensitive it could detect a tremor halfway around the world, but it could also measure movement of the Southern California faults tens of thousands of times stronger.

So how could one resolve the tiny jiggles on the chart recorder of an earthquake in Siberia and still accommodate the violent movement of the pen caused by local earthquakes? Richter's scale assumed that the machine was 100 km from the epicenter as a starting point. Each increment of one, on the paper chart, represents a tenfold increase in S-wave magnitude. Thus a movement of one 1/1000th of a millimeter represented a magnitude of 1; one 1/100th of a millimeter was 2, and so on. If you extend this, you'll see that a magnitude-7 earthquake would move the recording arm one meter. Thus, on a strip of recording paper less than 40 inches wide, it was possible to trap and measure the S-wave from every Earth movement reaching the seismograph.

You can also see that a magnitude 7 earthquake is 10 times stronger than one which measures a magnitude of 6. This tenfold increase (or decrease) for a 1-unit increase (or decrease) is referred to as a *logarithmic scale*. This varies from a *linear scale* such as 1, 2, 3, 4, and so on. The logarithmic scale makes both the Richter scale and the decibel very useful for describing the difference in numbers of greatly varying magnitudes.

So What's a Decibel?

The decibel is 1/10th of a Bel and is named after Alexander Graham Bell, the inventor of the telephone. *(The decibel is properly abbreviated as dB, with a capital B, because the root word, Bel, is capitalized. The same applies to the Volts and Hertz—also named for people—and is why microvolts are abbreviated μV, with a capital V, and the abbreviation for kilohertz is kHz.—ed.)* The decibel is defined as the smallest change in sound intensity that the human ear can detect. Keep in mind that the decibel means little more than this simple definition unless we know what levels are being compared.

A measurement in decibels must always be so many decibels above or below a given reference point. If a sound has 10 times the power of a reference (10 dB), we perceive it to be twice as loud. For example, if we increased the power output of a stereo amplifier from 10 watts (the reference level) to 100 watts, (a 10-dB increase) we would say that it was now twice as loud as before.

The accompanying table shows the extremes in sounds that we hear everyday and the relationship in decibels. The need for a logarithmic decibel scale becomes obvious when you consider that the softest audible sound has a power of about 0.000000000001 watt/square-meter and the threshold of pain is 1 watt/square-meter, or a total range of 120 dB.

Beyond Sound Measurements

Why do we need the decibel in electronics? Let's talk about radio frequency equipment rather than the sound output of your stereo. If you look in the instruction manual for your handheld radio, you'll see a specification for "spurious emission." The process of generating the signal your radio sends through the air creates many signals other than the one you want. If these spurious signals are not sufficiently suppressed, they can interfere with other radio services.

Ideally, the radio circuitry would eliminate these spurious signals. But this isn't

By Donald L. Stoner, W6TNS

Noise Levels in Decibels

Noise Source	Decibel Level	Noise Effect
Jet takeoff (25 meters)	150	Eardrum rupture
Aircraft carrier deck	140	Earphones at high level
Jet takeoff (100 m)	130	
Thunderclap, live rock music, chain saw	120	Human pain threshold
Steel mill, riveting, auto horn at 1 m	110	
Jet takeoff (305 m), outboard motor, power lawn mower, motorcycle, farm tractor, jackhammer, garbage truck	100	Serious hearing damage (8 hrs)
Busy urban street, diesel truck, food blender	90	Hearing damage (8 hrs)
Garbage disposal, dishwasher, average factory, freight train (15 m)	80	Possible hearing damage
Freeway traffic at 15 m, vacuum cleaner	70	Annoying
Conversation in restaurant, office, background music	60	
Quiet suburb, conversation at home	50	Quiet
Library	40	
Quiet rural area	30	
Whisper, rustling leaves	20	Very quiet
Breathing	10	
	0	Threshold of hearing

Table. Noise levels of common objects and activities, expressed in decibels (dB). Every increase of 10 dB represents a doubling of loudness. (Data courtesy Temple University)

possible in the real world. The best that can be accomplished is to suppress these unwanted emissions to a level that is significantly below the level on the desired transmit frequency.

How much is "significantly" less?" The FCC rules and regulations specify how much suppression is required for an amateur radio transmitter, and your manual tells you the specification for your unit. Usually, it's 60 dB.

More Is Less

But not all manufacturers give the specification the same way. Your manual may say "not less than 60 dB," "–60 dB or better," or "–60 dB or more." What does this mean? Let's say you're operating on the 1-watt position. The spurious signals are going to be less than the main signal, but by how much? If the spurious levels were suppressed by 10 dB, they would be 1/10th of the main power or 0.1 watts. If the manual said "more than 10 dB," it would actually mean less power than 0.1 watts.

Confusing? Not really. Read the last paragraph once again and the light will go on. If the specification stated "–10 dB or more," it would mean the same thing. More than 10 dB below 1 watt is some power level of less than 0.1 watts. Even if a lazy copy writer wrote that the spurious signal suppression was "more than 10 dB" (rather than –10 dB), you'd know that "minus dBs" were referred to, since the spurious output is obviously going to be less than the main power output signal.

Actually if the spurious suppression were only –10 dB, you would receive post cards from ARRL "Official Observers," or even a "pink slip" from the FCC, about the interference.

At –20 dB, the "spurs" would be less than 0.01 watts, –30 dB would be 0.001, –40 dB equals 0.0001 watts, –50 dB is 0.00001 watts and the goal, –60 dB represents 0.000001 watts of radiated power on frequencies where you *don't* want to transmit. This is virtually zilch (a highly technical term which is beyond the scope of this article).

Sometimes it's tough to get through to the other station with 1 watt of power. You can see that a 0.000001 watt signal is essentially non-existent. Hopefully, after reading this far, you can see that all three versions of 60 dB, given above, mean the same thing.

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Signal-to-Noise Ratio

Most of the time, the stations you hear on your handheld radio are strong and noise free. But what happens when the other station moves farther and farther away? The signal gets weaker and the background noise (both internal and external to the radio) starts to become apparent. If the station keeps moving away, the signal gets weaker and the noise gets louder. The difference between the signal level and the noise level is called the *signal-to-noise ratio* (SNR or S/N) and is expressed in decibels.

All radios create noise in their highly sensitive radio frequency amplifying stages. The hiss you hear with no signal input, or with the antenna removed, is actually the sound of electrons cruising through the radio circuitry. Some radios use very low noise transistors and sophis-

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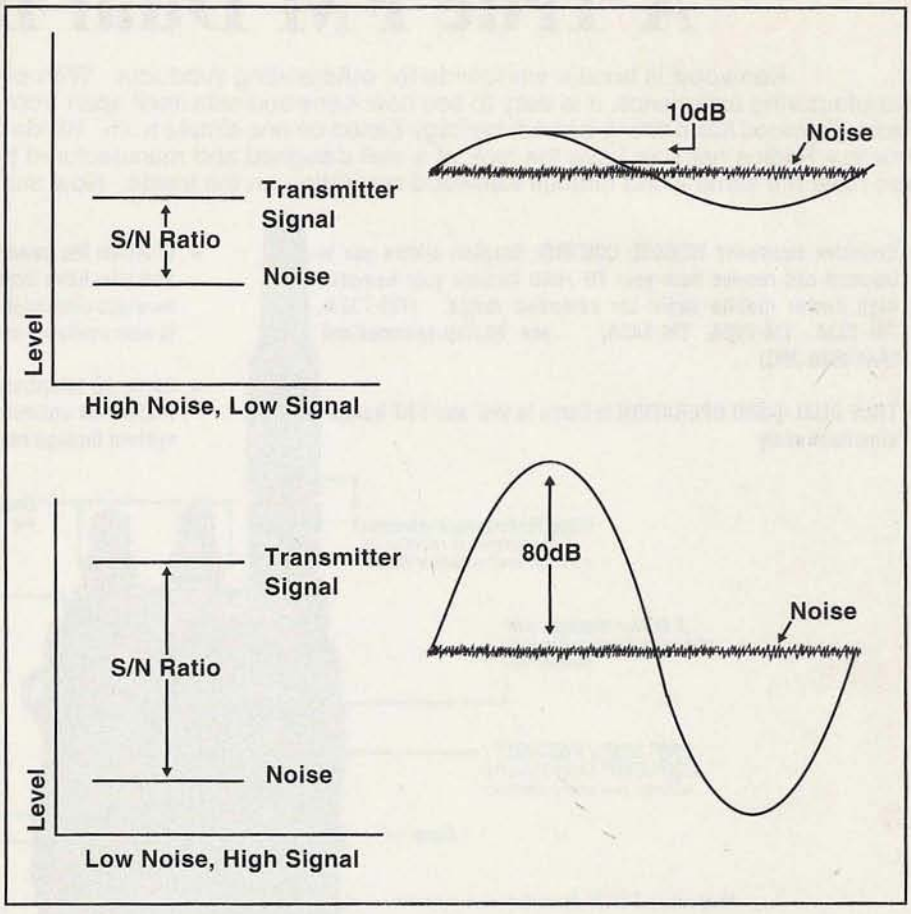

Figure. Signal-to-Noise Ratio (SNR) is a comparison of signal strength to the noise level on a frequency, expressed in decibels. A signal that's 10 dB above the noise is twice as loud as the noise level, but a signal with an 80 dB SNR is nine times louder than the noise.

ticated circuitry to minimize this noise. But if you're the engineer designing the handheld, how do you tell the customer how good your pride and joy is?

First, the engineer sets the volume control so the noise level, measured at the speaker, provides a specific reference; for example, 0 dB on a meter scale. Then he connects a signal generator to the antenna, injects a signal, and slowly increases its value. Once the noise level drops by, say, 20 dB (almost full quieting), the engineer notes the level of the generator output. Typically this will be 1 microvolt (1/1,000,000th of a volt) or less. Thus the specification for the radio would be 1 microvolt for a SNR of 20 dB.

In this example, the SNR is called *quieting*. In practice, a more critical measurement is generally used that includes figures for *interference* and *distortion* (*SINAD—Signal, Interference, Noise And Distortion*). Also, the noise reduction is usually specified at 12 dB. The manual for a five-year-old handheld that I use daily shows a 12 dB SINAD of 0.16 microvolts (truly excellent).

"The difference between the signal level and the noise level is called the signal-to-noise ratio (SNR or S/N) and is expressed in decibels....The measurement of antenna performance is another application for using decibels."

Power Output

Mr. Bell (or at least the measurement named for him) gets into all aspects of ham radio. If you want to increase the signal level of your 6-meter single sideband rig, you might add a linear power amplifier. Let's say the radio has a 100-watt power output rating. If you add a 1-kilowatt amplifier (1,000 watts), it would amplify your signal by 10 dB and your signal would be twice as loud as before. An expensive accessory, perhaps, but

when you are chasing DX (stations far away), an amplifier like this can make the difference between being heard and not.

Antenna Gain

A less expensive way to "soup up" your signal is to use a better antenna. This has the added benefit of amplifying received signals as well. The measurement of antenna performance is another application for using decibels. I'm sure you remember from studying for your license exam that you can concentrate the radiated signal from a dipole antenna by adding elements called reflectors and directors.

By redirecting and focusing energy that is radiated in unwanted directions by a dipole, it's possible to increase the *gain* of an antenna in a desired direction. The gain of this improved antenna, with respect to a dipole in free space (no earth, metal structures, buildings, etc.), is expressed in decibels. The ratio is the signal level at some distance, with respect to a dipole in space, compared to the signal level at the same point relative to a multielement beam antenna. (You'll typically see two types of antenna gain references—*dBi* and *dBd*. The *i* in *dBi* stands for *isotropic*, an antenna that radiates equally well in all directions. Such an antenna exists only in theory, but provides a common reference point from which to make gain comparisons. A gain figure measured in *dBd* refers to decibels of gain over a *dipole*. Each is an equally valid way to express antenna gain, but you should only compare dBi to dBi and dBd to dBd.)

A discussion of antennas, gain, types, polarization, and so on provides fodder for next month's column.

If You Want to Do the Math...

I've just hit the "high spots" in a dB discussion and glossed over many other points to salvage the nerve fibers of those who have difficulty with mathematics. For example, to calculate decibel ratios more or less than an even 10-dB value, you need to understand logarithms or, at a minimum, know how to use a log table. And there's a difference between the ratios of power, which we've just been discussing, and voltage.

The formula for the power ratios is:

$$10 \log(P2/P1)$$

but if one refers instead to voltage, the formula now becomes:

$$20 \log (V1/V2)$$

The reason for the difference is that power varies with the square of the voltage. You don't need to be able to do the math, though, as long as you know how to use the results of someone else's calculations to make comparisons based on decibel measurements.

In all of the above examples, I've used variable values for the reference. But often a specific reference is used. For example, if 1 milliwatt is assigned a value of zero, then we refer to values using this fixed reference as dBm (decibels per milliwatt). If 0 dBm is 1 milliwatt, then 10 dBm is 10 milliwatts, and so on. Or, if we use a zero reference of 1 microvolt (μV), then 20 dBμV is 100 microvolts.

Go Dabble in Decibels

Now aren't you glad I glossed over the nitty-gritty of decibels? However, this basic discussion should get you started in coming to grips with the devilish dB. You can learn more about them by purchasing an *ARRL Handbook* at your local radio store, or by mail from the CQ Bookstore.

For now, 73 Don, W6TNS

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